COMPOSITE GUN TUBE SUPPORT

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A composite gun tube support was designed for the main armament of the Future Combat Systems Mounted Combat System (FCS-MCS). The goal was to increase wheelbase for accuracy and to add stiffness to the gun tube while saving as much weight as possible. The initial tube support design was all titanium and weighed 207 lbs. By using composite materials rather than titanium, the tube support was reduced to 67 lbs, for a weight savings of nearly 70%. This paper will discuss the design, fabrication, and testing of the tube support and compare experimental test results with finite element models.

The tube support was designed for the FCS-MRAAS (Multi-Role Armament and Ammunition System) Swing Chamber Launcher. The swing chamber launcher provides the benefits of loading while the tube is elevated and stabilized, enabling a much simplified autoloader design, and minimizing weight and space claims. These benefits allow for faster firing rates in a smaller and lighter system. However, there are some drawbacks to this design. In a conventional gun tube design, the chamber would be part of the gun tube and the tube could be gripped in two places, providing an appropriate wheelbase to help with accuracy. With the swing chamber, the tube is screwed into the breech ring and is thus held in only one location. This single support point, though, is insufficient to keep tube deflections at an acceptable level.

In order to keep the benefits of the swing chamber launcher while minimizing its problems, a composite tube support was designed which bolts to the front of the breech ring and extends 1060 mm forward where it clamps onto the gun tube. This tube support provides additional stiffness and also functions as the rear part of the tube's environmental shroud. Two tube supports were built, assembled, and then test fired at Aberdeen Proving Grounds.

The initial baseline design for the tube support consisted of a 15 mm thick titanium shell, changing from a rectangular cross section near the breech end to an octagonal one in the front. The goal was develop a design consisting of a composite shell with titanium end frames, which had the same shape and performance while minimizing weight. A three-dimensional finite element half model was created using Abaqus for both tube supports and included the gun tube and other necessary hardware. The titanium model used linear solid elements and predicted a vertical muzzle deflection of 64 mm under a six g static load. The initial composite tube support model utilized shell elements and smeared laminate properties, easily allowing different candidate laminates to be assessed. An optimal design using IM7 and M55J carbon fibers in a cross ply laminate with a thickness of 3.81 mm was selected. A detailed ply-by-ply model of this laminate was then created and predicted a vertical muzzle deflection of 70 mm. This vertical deflection was slightly larger then the titanium design but was deemed acceptable as the weight was reduced by almost 70%.

Figure 1. Manufacture at Benét

The primary composite tube support was constructed in house at Benét Laboratories using pre-

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OMB No. 0704-0188

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1. REPORT DATE **00 DEC 2004**	2. REPORT TYPE **N/A**	3. DATES COVERED **-**
4. TITLE AND SUBTITLE **Composite Gun Tube Support**		5a. CONTRACT NUMBER
		5b. GRANT NUMBER
		5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER
		5e. TASK NUMBER
		5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **US Army RDECOM-ARDEC Benét Laboratories, Watervliet, NY**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S)
		11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADM001736, Proceedings for the Army Science Conference (24th) Held on 29 November - 2 December 2005 in Orlando, Florida. , The original document contains color images.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**UU**	**2**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

impregnated carbon fiber epoxy tape with the hoop layers (IM7) being wound in a filament winding machine while the axial layers (M55J) were applied by hand. The completed layup was vacuum bagged and cured in an autoclave. The backup support was contracted out and constructed by tape placement. After the curing was complete, the supports were cut to the proper length and fitted to the titanium end frames, which had been machined to fit, and then bonded together. Tri-directional strain gauge rosettes were then applied to the primary tube support to monitor and record strains during testing.

Before the gun could be fired, a non-destructive evaluation (NDE) was performed on the tube support to ensure its safety. This was done by performing a load test in parallel with an acoustic emission test. The launcher assembly was mounted on a hard stand with the gun tube held horizontally. Weights were then hung from the muzzle end of the gun tube in order to measure strains in the tube support and the vertical deflection of the end of the gun tube. With 200 lb hung at the end of the tube, the experiment and the finite element model both had a vertical deflection of 28.5 mm. The strains were not as close but had similar trends, so the parameters of the finite element model were modified to adjust for this. The loading and unloading of the tube was repeated three times to gather data for the acoustic emission test. No acoustic events of significance were recorded, so the tube support was deemed safe for the firing test.

After the tube support was deemed safe, the gun was test fired. The cannon was fired in both direct (0º elevation) and indirect (30º elevation) fire modes at pressures ranging from 138 MPa to 552 MPa with a total of 11 rounds. Data was taken from the strain gauges at a rate of 200 kHz for one second. Three accelerometers were also attached to the front of the support to measure axial, vertical, and horizontal accelerations. They were sampled at the same rate but for 0.5 seconds. The responses were largely as expected with overall strain levels being around 150 microstrain. The response for the low-pressure shots was higher than expected, but this was later shown to be due to interaction between the projectile and the gun tube. Also there was a higher level of damping during the high-pressure shots than expected. After firing, the support was inspected by ultrasonics and some voids were found in the bond areas. The non-fired backup support was found to have the same voids, so it was decided that this was a manufacturing defect.

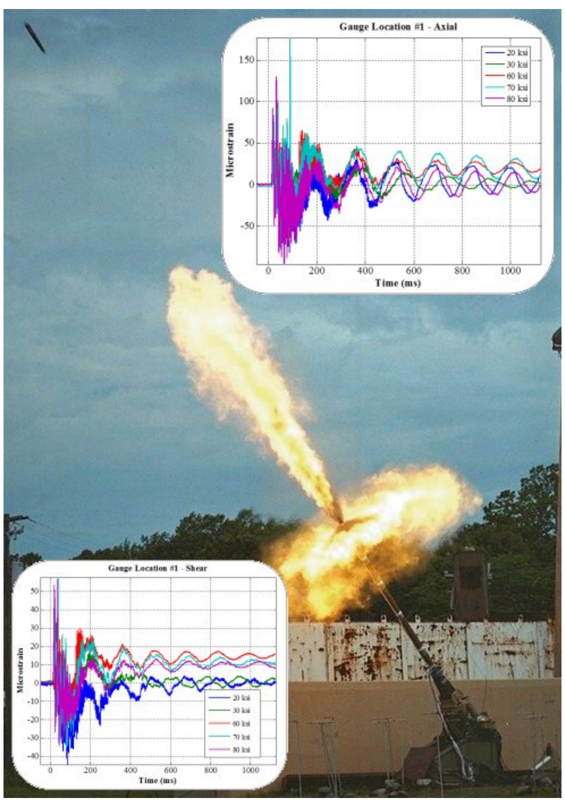

Figure 2. Indirect Firing with Strain Plots

A composite tube support was designed to increase the stiffness of the gun tube while also providing a longer wheelbase for improved accuracy. This design was nearly 70% lighter than an equivalent all titanium version and performed flawlessly during its firing tests.